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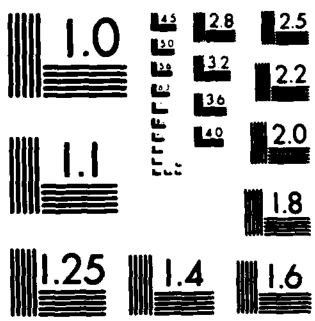

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FOREIGN TECHNOLOGY DIVISION

AUTOMATION OF ELECTRIC POWER SYSTEMS

(Selected Articles)

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AUTOMATIC BIAS CONTROL (ABC) FOR LASER

by

Lu Wubin

Nanjing Institute of Automation Research

ABSTRACT

This paper describes an experiment on the automatic control of laser bias current in a digital system by the "total electronic method".

In this paper, the author also presents approximate expressions for junction temperature and threshold current with the consideration of bias current, and makes qualitative and quantitative analyses on the non-ideal saturation characteristic for the junction voltage, which is the theoretical basis of the "total electronic method" for automatic control of bias current.

Semiconductors are small and light, have a high luminosity and a rapid speed of response. They are easy to control and are ideal for the remote transmission of large quantities of information. They are also one of the determinant factors in the reliability of fiber optical communication systems.

The laser is a type of threshold device. Its junction voltage, optic output and high frequency control characteristics are

related to injection current. It is necessary to supply the laser with a suitable injection bias in order to obtain a fixed output and to raise modulation speed for reasonable working conditions. Furthermore, threshold influences temperature by producing an increase after prolonged use. Bias irregularities cause changes in output and a deterioration in high frequency modulation. There is also an increase in noise and the laser may even be damaged. Consequently, it is necessary to implement an automatic control on the laser bias to adapt to changes in threshold and thus preserve the normal operation of the laser. The automatic control of lasers is an important task in research on fiber optical communication systems.

The problem of unstable optical power in laser output has been the focus of a great deal of research by overseas' scholars. They have proposed several different methods of automatic power control (APC)[1~4].

In 1978 A.ALBANESE of Bayer Laboratories proposed a method of bias control which was out of the ordinary. This was known as the 'total electronic method'. This method is simple, does not use

photoelements and uses changes in junction voltage to implement automatic control.

I. AUTOMATIC BIAS CONTROL (ABC)

1. Control Principles

If the laser junction voltage is V_j, then [6]

$$V_j = \begin{cases} 2kT_j/e\, Ln(I/I_{s0}+1) & (I<I_{th}) \\ E_g/e & (I \geq I_{th}) \end{cases}$$

If the laser bias is lower than the threshold, then $I_b < I_{th}$, and the modulation current is I_m. See fig. 1. Obviously when $I_b \neq I_{th}$ there will be an error voltage V_e present between the junction voltage and saturation value.

$$V_e = \begin{cases} I_e R_j & (0 < I_e < I_m) \\ I_m R_j & (I_e > I_m) \end{cases} \tag{1}$$

where

$$R_j = dv_j/dI \quad (I = I_{th}) \tag{2}$$

$$I_e = I_{th} - I_b \tag{3}$$

By taking V_e and gauging it transforms it into the error current I_e , this satisfies

$$I_b = I_{b0} + YV_e = I_{b0} + KI_e \tag{4}$$

Where $K = YR_j$, $I_{b\,o}$ is the fixed bias current, Y is the admonitized amplification coefficient of the error voltage and K is the amplification coefficient of the error current. From (3) and (4) we get

$$I_b = I_{th} - (I_{th} - I_{bo})/(1+K) \qquad (5)$$
$$I_e = (I_{th} - I_{bo})/(1+K) \qquad (6)$$

When $K \gg 1$, we get the following from (5)

$$I_b \cong I_{th} \qquad (7)$$

Although we have always thought that the junction voltage would be saturated above the threshold point, this was not the case. Furthermore, because of the presence of noise and external interference, there was always a voltage present in the amplifier. If this voltage is equivalent to the output terminal and is called V_n, the corresponding current will be I_n

$$I_n = V_n / R_j \qquad (8)$$

considering the presence of I_n, this time the bias I'_b will be

$$I'_b = I_{bo} + K(I_e + I_n) \qquad (9)$$
$$I_{th} - I'_b = I_e - K I_n \qquad (10)$$

Obviously, when $KI_n > I_t$, $I'_b > I_{t\ h}$. This is unexpected during digit modulation. For this reason, a threshold voltage ΔV is inserted which makes $\Delta V \gg V_n$ and its polarity opposite. When $V_e > \Delta V$, I_b increases in the direction of $I_{t\ h}$ and when $V_e \leq \Delta V$, $I_e = 0$. In this way the laser is able to correct threshold point bias.

On the basis of the above analysis, a flowchart is established relating $I_{t\ h}$, I_b, I_e, V_e, V_j, ΔVY and $I_{b\ o}$. This is shown in fig.2.

2. <u>Control System Structure</u>

The control system is as shown in fig.3.

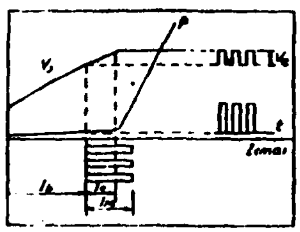

Fig.1

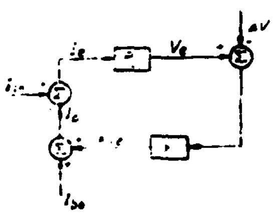

Fig.2 Flowchart

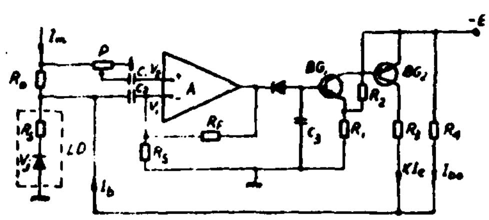

Fig.3 Components of the ABC System

If the operational amplifier output voltage is V_1, V_2, then

$$V_1 = IR_s + V_j \tag{11}$$
$$V_2 = [I(R_0 + R_s) + V_j]P \tag{12}$$

Adjusting P satisfies

$$P = R_s/(R_s + R_0) \tag{13}$$

then $$\Delta V_i = V_1 - V_2 = R_0 V_j/(R_0 + R_s) \tag{14}$$

If the closed cycle gain of the operational amplifier is A, then

the output voltage

$$V_o = A\Delta V_i = AR_0 R_j I_e/(R_0 + R_s) \tag{15}$$

After V_o has undergone peak value detection it is transformed

into direct current KI_e, consequently

$$I_b - I_{b0} \cong \beta_2 V_o/R$$
$$K = A\beta_2 R_0 R_j/R(R_0 + R_s) \tag{16}$$

In the experiment the Chinese Academy of Science Semiconductor Research Institute's DHL-X-N AlGaAs double heterojunction semiconductor laser was used. This was concerned with the parameters:

$$R_0 = 5\,\Omega,\ R_s = 3.6\Omega,\ R_j \cong 0.46\Omega,\ \beta_2 = 50,\ R = 200\Omega,\ A = 2000,\quad K \cong 700.$$

Pulse modulation was used with a repetition rate of 2.2 MC, a duty ratio of 50%, I_m= 20ma, I_{th}= 113ma. These are shown in a curve in fig. 4.

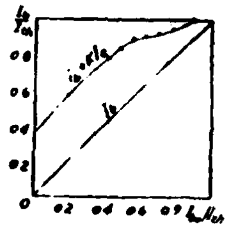

Fig. 4 Curve showing relationship of $\frac{I_b}{I_{th}} \sim \frac{I_{b0}}{I_{th}}$

II. STABILITY ANALYSIS

1. The Influence of Bias Current on Junction Temperature and Threshold Current

It is common knowledge that the factors influencing threshold current are numerous. It would be difficult to find a precise formula to express the relationship between these factors. However, as far as the high quality double heterojunction semiconductor laser is concerned, one of the main factors influencing threshold current is temperature. This can be expressed by using an approximate relation formula(7).

$$I_{th} \cong I_{tha} \exp[(T_j - T_a)/T_0] \qquad (17)$$

where T_j represents the junction temperature ($^{\circ}K$), I_{tha} is the threshold current when the junction temperature is T_a.

T_o is approximately 100 to $150^{o}K$.

From (17) we can see that I_{th} increases when T_j rises. After bias current I_b is introduced, the presence of series resistor R_s causes a rise in junction temperature. This rise in turn causes an increase in threshold current. Under conditions of automatic control the following process emerges

$$T_j^{\uparrow} \longrightarrow I_{th}^{\uparrow} \longrightarrow I_b^{\uparrow} \longrightarrow T_j^{\uparrow}$$

But by how much does I_b make the junction temperature rise? Can this exceed the allowable range of the component? This is the question we are concerned with here.

When the current passes through the laser, the R_s consumes power by generating heat which is sent outside after passing through the surrounding environment. When the amount of heat produced by the laser core and the amount of heat emitted per second reach a dynamic equilibrium, the heat equilibrium equation below exists

$$P_Q = K(T_j - T_a) \qquad (18)$$

where P_Q represents the power consumed by the laser (gas), K is the heat conductivity and shows the power emitted by the unit

temperature difference. Moreover

$$K=1/R_t \qquad (19)$$

where R_t is the thermal resistance ($^{\circ}$K/gas).

If the bias current is I_b, the influence of the modulated signal current on the junction temperature can be overlooked, then

$$P_0=I_b^2R_s \qquad (20)$$

From (18), (19), (20) we can explain

$$T_j=I_b^2R_sR_t+T_0 \qquad (21)$$

If we take (21) and substitute it for (17), we get

$$I_{th}=I_{th}(T_0)exp[I_b^2R_sR_t/T_0] \qquad (22)$$

The smaller I_b, R_s, R_t are the smaller the influence on the threshold current will be. If $R_s \doteq 6\,\Omega$, $R_t=50^{\circ}$K/gas, $I_b=100$ma, $I_{th}(20^{\circ}C) \doteq 100$ma, and T_0 is taken as 100°K, then

$$I_{th}=100exp[I_b^2R_sR_t/T_0]\cong 103ma$$

Obviously because of the influence of I_b, I_{th} will be increased by 3 milliamperes. This explains the reason for the I_{th} of the pulse working being smaller than the I_{th} of the direct current working.

2. The Instability of Optical Output

If laser optical output is P, the differential power gain is S, the modulating current injected into the laser is I_m, then

$$P=S(I_M-I_{th}) \tag{23}$$

$$K_0=dp/dI_{th}=-S \tag{24}$$

After adding automatic bias control, the current that passes through the laser is

$$I=I_b+I_m \tag{25}$$

This time the rate of change of optical output in the threshold current is

$$K=K_0/(1+K) \tag{26}$$

and the rate of change of optical output in the junction temperature is

$$dp/dT_j=K_0I_{th0}/(1+K)T_0\exp[(T_j-T_a)/T_0] \tag{27}$$

Obviously, after adding automatic bias control, the degree of output instability in the threshold current and junction temperature will drop K times.

3. The Non-Ideal Characteristic of Junction Voltage

The rate of change of laser junction voltage below the threshold point can be found by using the increment resistor $R_{j\,i}$. If $T_j = 300^{\circ}K$, $I_{t\,h} = 100ma$, then near the threshold point

$$R_{j\,i} = dV_j/dI \cong 0.52\Omega$$

In other words, near the threshold point there will be a change in junction voltage of 0.52 millivolts for every change in current of 1 milliampere.

Above the threshold point, because there is separation at the quasi-Fermi level in the conduction and valence bands, the distribution of the number of particles formed in the active region is reversed. The number of electrons at the lower part of the conduction band will exceed the number of electrons at the upper part of the valence band. The protons and holes recombine at an extremely high speed to form laser oscillations. For this reason P-N junctions almost have no blocking effect on the current. The junction voltage is only determined by the width of the forbidden band Eg.

Theoretical analysis and test results indicate that the width of gallium arsenide forbidden bands decreases when there is a rise in temperature. The rate of change at room temperature is $dEg/dT_j =$ -3.95×10^{-4} electronvolts/^{o}K [9-11]. Therefore, the relationship between the width of the G_aA_s forbidden band and the junction temperature is

$$Eg(T_j) = Eg(0) + T_j dEg/dT_j \tag{28}$$

where Eg(0) is the width of the forbidden band at any temperature and $Eg(T_j)$ is the width of the forbidden band at junction temperature T_j.

R_{j2} represents the rate of change in current when the junction voltage is at the threshold point or above it. Therefore we can try to get

$$R_{j2} = dV_j/dI = -2IR_sR_t \times 3.9\times10^{-4}$$

If $R_s = 6\,\Omega$, $R_t = 50^{\circ}K/$ gas $I_m = 25ma$, then

$$R_{j2} = 0.005\Omega$$

In this example, when $I \geqslant I_{th}$ there is only a change of 5 microvolts in voltage for every 1 milliampere change in current. This is far smaller than the rate of change below the threshold point.

4. <u>The Influence of Differential Power Gain</u>

Optical output power P is directly related to S. S decreases as temperature rises. See fig.5. The reason for this is that the influence of temperature on the concentration n_i of the original carrier is extremely great. A raise in temperature causes interior absorption to increase greatly and the inner quantum efficiency and gain parameters to drop. There is naturally a drop in output. Limiting conditions occur when n_i is near doping concentration. P-N junction characteristics are not present and what is known as intrinsic conductivity appears.

Differential power gain gradually drops with respect to time used. See fig.6[12]. As S falls the inner flaws of the laser begin to increase.

A drop in S produces a reduction in optical power and influences power stability. That this type of influence alone depends on bias control is difficult to avoid.

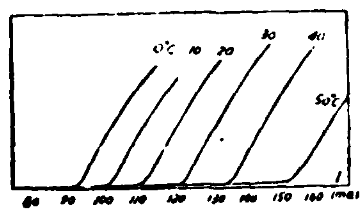

Fig.5 Curve showing P-I characteristics under different temperatures

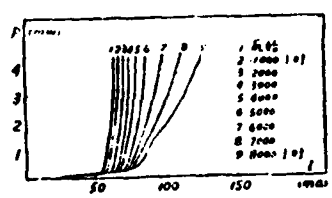

Fig.6 Relationship between P-I and time used

III. CONCLUSION

1. After implementing automatic bias control, there was an increase in optical power stability.

2. The introduction of bias current caused a slight rise in junction temperature and an increase in threshold current.

3. The rate of change in junction voltage above the threshold point was not zero, but was a lot less than when it was below the threshold.

4. The principles of the 'total electronic method', according to theoretical analysis, may also be used in television analog control systems as well as in digital control systems.

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HITACHI'S BCAM - A COMMUNICATION CONTROL PROGRAM

Zhang Yaozong

I. INTRODUCTION

The process of converting information by computer via communication lines and a terminal is different from that using other peripheral devices (e.g. line printers). The reasons for this are:

1. Data generation and program execution are asynchronous.
2. Communication lines may be easily affected by external interference and require close checking and rectification as well as counter measures for failure recovery. A fairly complex communication control sequence thus results.
3. The equipment which can be linked with computers via communication lines is varied. It can consist of a general terminal or a computer or it can be linked with a communication network. Compatibility at all levels is therefore necessary.

This makes the input/output control of communication lines by computer much more complex than by other peripheral devices. In order to alleviate the user's programming load, we have to make the time taken by the user to transmit data through communication lines the same as that taken to use other peripherals. This means adding a communication control program to the software system.

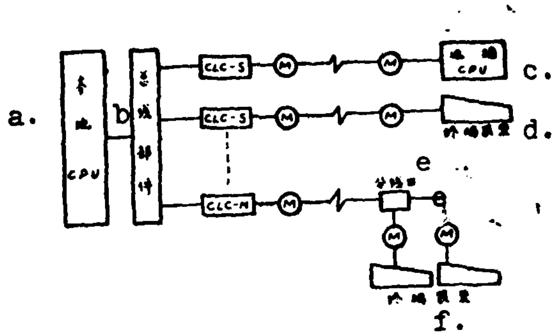
BCAM (Basic Communication Access Method) is this type of program and was developed by Hitachi for their 'H' series of computers.

BCAM supports a working transmission speed from 200 BPS to 48,000 BPS under BSC communication regulations. This system has the following characteristics.

- It can support 1:n of communications. When the speed is 200 BPS, n=64.
- It can serve many communication user programs simultaneously.
- It can simultaneously handle the transmission and receipt of signals on many circuits.
- It can support many kinds of transmission control sequences.
- The user does not need to be aware of the complex

transmission control and can, therefore, carry out data conversion from the terminal. This is the same as using regular peripheral equipment.

II. THE BCAM SUPPORTED HARDWARE SYSTEM



KEY:

a. local CPU
b. mainframe
c. remote terminal
d. terminal
e. line switching device
f. terminal

The local computer above is the Hitachi 'H' Series computer. The local and remote terminals may be different models but must be compatible.

The CLC-S and the CLC-H are communication controllers produced by Hitachi. Their specifications are given on the next page.

Communication controllers are responsible for the following tasks within the system:

- Along with the CPU carrying out electrical connection with the MODEM
- Simultaneously receiving and transmitting characters
- Distinguishing communication control codes
- Transparency processing
- Monitoring response time
- Forming and transmitting checking codes. Carrying out check at receiver terminal

III. BCAM SUPPORTED COMMUNICATION REGULATIONS

BCAM supports BCS communication regulations and can use four kinds of computer codes. These are; JIS-7, JIS-8, EBCDIC and USASCII.

In BCS regulations the text is divided into two;

Text
- Information text
- Monitor text
  - Forward monitor text (same direction as information text)
  - Backward monitor text (opposite direction of information text)

Each type of text is a character sequence of which at least one character is a control character. Table 1 lists ten common transmission code characters as they are used in texts.

TABLE 1: BASIC TRANSMISSION CODE CHARACTERS (PARTIAL LIST)

Transmission control character	Chinese name	Text	Function
SOH	序始	I	Start of heading, in information text
STX	文始	I	End of heading, start of text
ETX	文终	I	End of text
EOT	送毕	FB	End of transmission, inform other party
ENQ	询问	F	Enquire of other party, request reply
ACK	确认	B	Acknowledge reply
DLE	转义	O	In conjunction with succeeding character(s) forms escape sequence
NAK	否认	B	egative response
SYN	同步	O	Synchronous idle character
ETB	组终	I	End of transmission block character

Key: I: Information text F: Forward monitor text

B: Backward monitor text O: Other

A COMPARISON OF THE SPECIFICATIONS OF CLC-C AND CLC-H

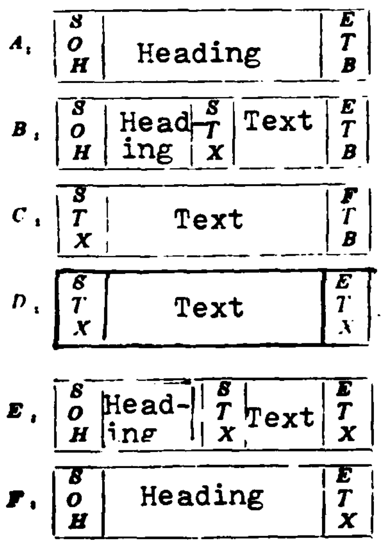
Item	CLC-S	CLC-H
Suitable range	Low speed circuit	Mid, high speed circuit
Communication speed	75～1 200 BPS	2400～48000 BPS
Communication mode	Half-duplex	Half-duplex
Same period mode	Start stop simultaneous	SYN
Error control	VRC and LRC	CRC mode (EBCDIK) $X^{16}+X^{15}+X^{2}+1$ $X^{16}+X^{12}+X^{5}+1$ VRC and LRC ($JIS_{7,8}$ or USASCII
Control code	JIS_7 bit JIS_8 bit EBCDIK, USASCII	EBCDIK, JIS_7 bit JIS_8 bit USASCII
Special functions		Supports BSC
		Supports transparency code (8 bit only)

BCAM's information text has the following form.

$$\left\{ \begin{array}{l} (A)^n(B)^1(C)^nD \\ (A)^nE \\ F \end{array} \right\}$$

(X) indicates that x may not appear or can appear as many as n times.

A,B,C,D,E,F are distinguished in the following sequence:



In monitor text BCAM permits the following types of choices.

CALLING SEQUENCE

Order	Calling character	Comments
1	EOT SA UA ENQ	SA- station Address UA- Unit Address
2	SA UA ENQ	
3	SA ENQ	
4	ENQ	
5	Other	Used in special cases (chosen at random)

RESPONSE SEQUENCE

Order	Response character	Comments
1	ACK NAK	One only ACK/NAK
2	ACK ACK NAK NAK	Twice in succession ACK/NAK
3	DLE ACK DLE NAK	Alternately ACK/NAK
4	DLE 0 DLE 1 NAK	Alternately ACK/ Absolutely NAK
5	Other	Used in special cases (chosen at random)

URGENT RESPONSE CHARACTER SEQUENCE

Order	Urgent response character	Comments
1	Non-urgent characters	
2	ENQ	
3	ENQ ENQ	
4	DLE ENQ	
5	Other	Used in special cases (chosen at random)

END CHARACTER SEQUENCE

Order	End character	Comments
1	EOT	1 end character
2	EOT EOT	2 successive end characters
3	EOT EOT	1 successive end character repeated
4	EOT EOT EOT EOT	2 successive end characters repeated
5	other	Special cases (chosen at random)

In each specific application system, one kind of sequence may be arbitrarily chosen from these sequences. However, each party must make the same choice.

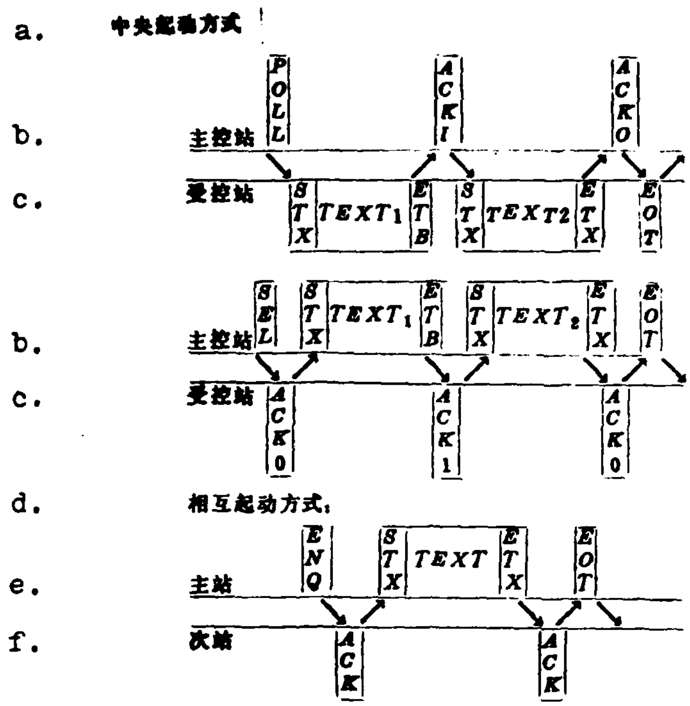
BCAM supports two types of transmission control modes: line-control mode and interactive mode.

In line-control mode, each communication line has one (and only one) main controller. The other terminals are receivers, and are periodically queried by the controller. It interrogates each terminal in turn if it has something to transmit. When the

controller wants to receive a message, it does polling to the other party so that it will transmit a message. It, therefore, becomes the transmission controller and the controller becomes the secondary station. When the controller wants to transmit, it send out SEL to the other party. This orders the other party to prepare to receive a message. The other party becomes the secondary station.

In interactive mode, the power of the two communicating parties is equal. Any of the two parties has the right to send a message at any time. The station which first seizes the power to transmit is known as the main station. The other is called the secondary station. If both stations request to transmit at the same time, then a message is first sent by the station for which priority had previously been determined.

The normal communication process of these two modes is set out below:



KEY:

a. line-control mode

b. controller

c. receiver

d. interactive mode

e. main station

f. secondary station

IV. ERROR CONTROL

External influence on communication systems is extremely great. As a result, errors may easily be produced. Therefore, they need to have strong and powerful error monitoring and feedback capabilities.

In the present system there is complete hardware/software coordination.

1. Code Check Error

For circuits using CLC-S interface

- A complete VRC by the CLC-S
- An LRC by the BCAM

For circuits using CLC-H interface

- A complete VRC of CLC-H hardware
- Produce CRC code (EBCDIC code)
- Produce and check LRC code ($JIS_{7,\ 8}$ or USASCII code)

2. Time Monitoring

Time monitoring of the communication process was carried out on each step by BCAM. When it was not possible to complete certain steps within a determined time limit, incorrect informa-

tion was sent out.

In particular, the following 7 types of time were monitored.

Fig. 2 shows an actual case of time monitoring

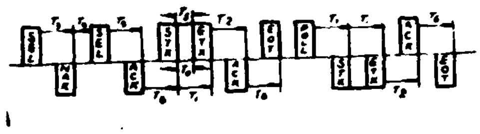


Fig. 2 Time monitoring

TIME CLASSES

Order	Time	Function
1.	T_1	Time from start to end of text
2.	T_2	Time from when text or urgent response character sent until received
3.	T_3	Time from when initializing character sent until response received
4.	T_4	Character interval when text received
5.	T_5	Character interval when text sent
6.	T_6	Time from when response sent until STX or SOH received
7.	T_7	From receipt of negative acknowledgement to initializing character until character resent

3. Error Correction

In accordance with communication stipulations, a negative response character, or any other relevant character, is sent by BCAM under the following conditions:

1. After the receiver has detected an error code
2. There is an extended breakdown for any reason
3. The receiver is unable to receive at anytime

The information is resent by the sender and communication is resumed according to the diagram. If normal communications still cannot be resumed after repeating this procedure for a previously determined number of times, then a report is made to the user so that appropriate recovery measures may be taken by the user program.

V. BCAM USER INTERFACE

The user program only requires the use of 3 instructions supplied by BCAM before data communications can be conveniently realized. These 3 instructions are:

RCOM

WCOM

HALTC

RCOM is used to receive information from the other party and WCOM is used to transmit information. On the instruction parameter card are the circuit number, predetermined calling sequence, sender and receiver data area address and ECB card address.

HALTC is used to discontinue the circuit while waiting for the receive condition. Its parameter is only the circuit number. This instruction is useful when in the interactive mode.

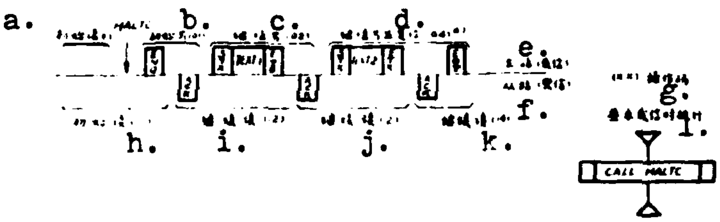
After BCAM has accepted these instructions, a parameter suitability and feasibility test is carried out. The test results (by means of an accumulator) and control are all returned to the user program. When these instructions have been correctly accepted, the WAIT instruction is sent by the user program in the appropriate place until the receiver or sender has finished. At the same time, BCAM implements data communications by means of the CLC. This process is carried out simultaneously with the user tasks. Once the transmission is completed, BCAM sends out the Post instruction and once again activates the user tasks. A report on the condition of the transmission is sent to the user through ECB.

The several kinds of RCOM and WROM operation codes

supply the user with a wide range of communication control functions. The user can choose various types of operations according to his needs, so as to realize the required communication control sequence.

Table 2 lists some actual examples of these operations codes.

Fig. 3 is a schematic flowchart which uses the sender and receiver communication user program in the interactive mode.



KEY:

a. start READ

b. start WRITE

c. cont. WRITE

d. cont. WRITE and relocate

e. sender

f. receiver

g. operation code

h. start READ

i. cont. READ

j. cont. READ

k. cont. READ

l. request transmission execution

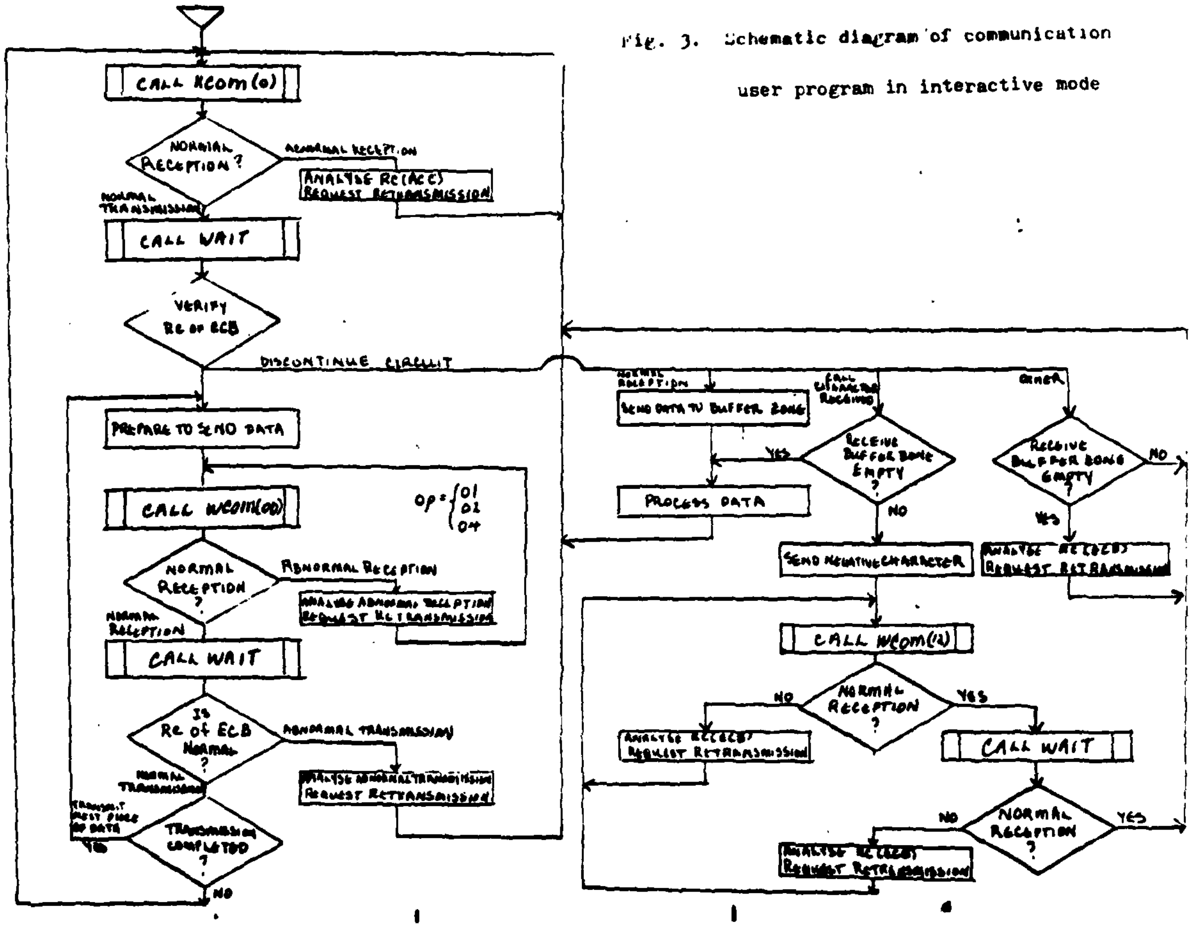


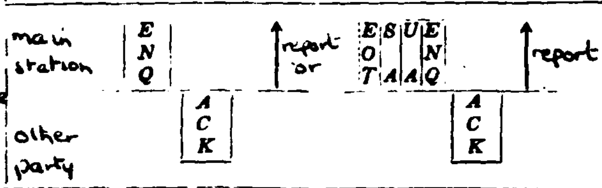
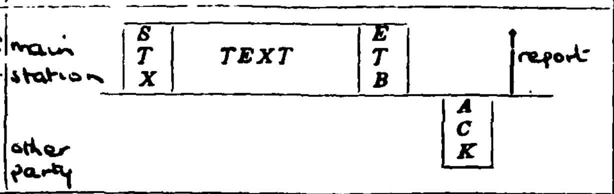
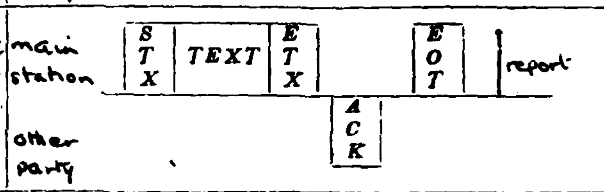
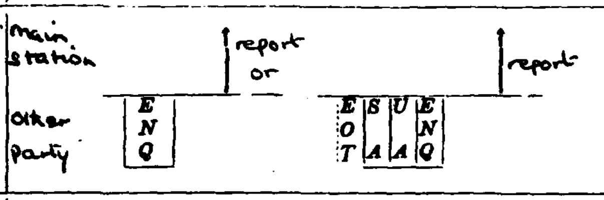
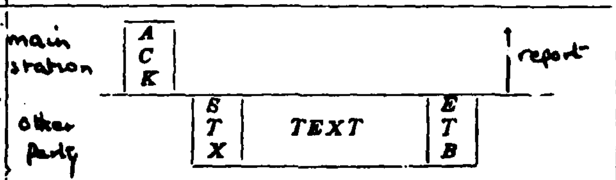
Fig. 3. Schematic diagram of communication user program in interactive mode

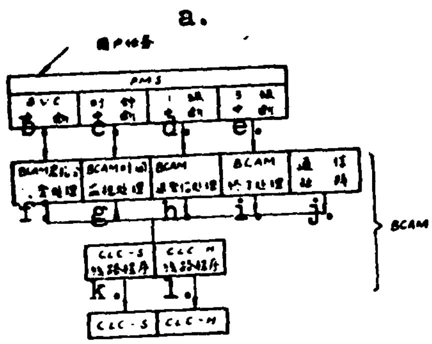
VI. THE POSITION AND COMPOSITION OF BCAM IN THE SOFTWARE SYSTEM

In the H-80 series, BCAM is supplied as an OS subsystem. It is located between the PMS main part of the OS) and the communication controller. Fig. shows its principal components.

In a particular application system, if there is insufficient BCAM, it is necessary to have a matching series of user task groups before data communication can be realized, as in Fig. 5. ECAM is an intermediate task of the user task groups and BCAM interface. BCAM is in charge of handling communication commands and ECAM has the task of sending out the commands. Other tasks are completing preparation for data receiving and transmission, handling data receiving and handling breakdowns and recovery. These tasks change when there are differences in the applied system. For example, the writer, in drafting another paper, used the SDS system of the electricity department's communications office as the background, so as to give a detailed presentation of the capabilities and structure of this group of tasks and their interrelationship.

TABLE II. PARTIAL LIST OF RCOM/WCOM OPERATION CODES

Operation	OP Code	Action	
Start WRITE	$(01)_{16}$	send start character, receive response character	
Continue WRITE	$(02)_{16}$	send information, receive response character	
Continue WRITE and relocate	$(04)_{16}$	send information, receive ACK character, send EOT character	
start READ	$(11)_{16}$	receive start character	
Continue READ	$(12)_{16}$	send ACK character, receive information	



KEY:

a. user tasks

b. relay

c. time relay

d. 1 stage relay

e. 3 stage relay

f. processing BCAM instruction

g. BCAM time monitoring

h. BCAM reception and transmission

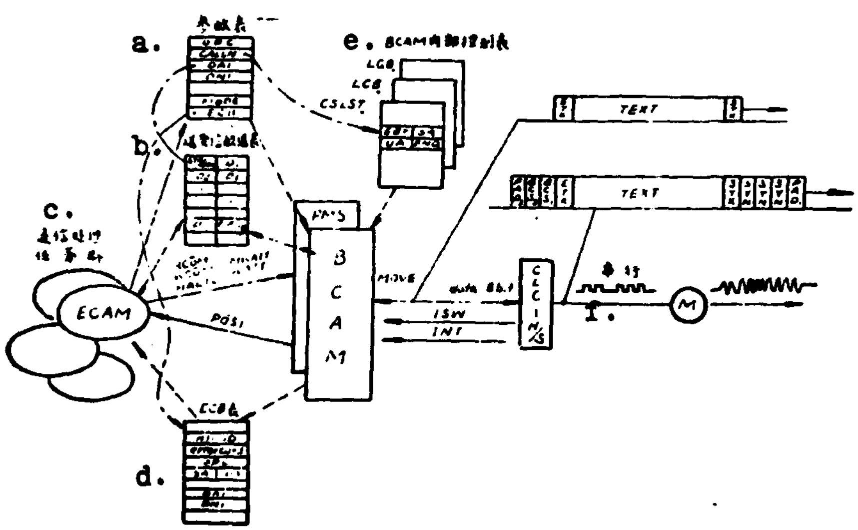
Fig. 4. The Composition of BCAM

i. BCAM final processing

j. communication matrix

k. CLC-S circuit program

l. CLC-H circuit program



KEY:

a. parameter card

b. transmit/reception data card

c. info. processing task groups

d. ECB card

e. BCAM internal control card

f. series

Fig. 5. Communication data flowchart

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